Institution: University of Birmingham

Unit of Assessment: UOA 14 – Civil and Construction Engineering

Title of case study: Improving Road Investment Appraisal

Summary of the impact

HDM-4 is the most widely used system for road investment appraisal and decision making, generating improvements in public policies and services. Economic development and road agencies in developing countries are major users of the tool. HDM-4 has become the *de facto* standard used by the World Bank for its road investment appraisals and has been used to assess more than 200 projects since 2008, with some $29.5bn of World Bank loans, credits or grants drawn-down to fund these. Uptake of the tool has led to the commercial success of HDMGlobal, a consortium which manages the distribution and development of the software under exclusive licence from the World Road Association-PIARC, with revenues of £1.6m generated since 2008. HDM-4 has also been utilised for economic assessment and road systems investment management in the UK.

Underpinning research

An international effort was undertaken from 1993 to develop improved road investment appraisal methods (HDM-4), with research and development centred at the University of Birmingham. This study built on an existing Highway Design and Maintenance Standards model, HDM-III, extending and developing it as described below.

Research to develop HDM-4 and its constituent models

Research was carried out to update and calibrate the existing technical relationships in HDM-III, produce additional technical capabilities for dealing with traffic congestion, non-motorized vehicles, concrete pavements, drainage, environmental impacts, safety effects, incorporate an energy balance framework and improve system design, software and the applications framework for use at various levels of planning, budgeting, appraisal and management of roads. (references 1-3) The end product of the studies was a completely new Highway Design and Maintenance Standards model and an associated software package (collectively known as HDM-4) . The work was funded via a number of research grants between 1993 – 2001: four World Bank Grants: Special Grants FY96, FY97, FY98 & PMGX55263; three Overseas Development Agency grants; ENA 832/921/007; R5486, R6472 and one World Road Association-PIARC grant HDM009.

Continuing research has been carried out to refine the road deterioration models further (2007 – 2011); develop predictive techniques for pavement failure (2002 – 2006 & 2009-date) and further consider the energy balance framework for appraising road projects (2008 -2012: 1851 Royal Commission Fellowship).

Major research work was also carried out at the same time to improve the quality of the data that was needed as input when HDM-4 is used. Two major research projects investigated: i) a statistical approach to overcome data quality issues, involving collaboration between the HDM-4 team and statisticians at Birmingham, which led to novel methods of determining defect models which could be employed in HDM-4 (1990 – 1996: EPSRC Grant Number GR/J43479); ii) means of enhancing the quality of road data which devised new techniques for objective measurement of which the most sophisticated was the prototyping of high speed parallel processing of digital images of the roads surface, the products of which are used throughout the world (1993 – 1998: EPSRC GR/H 80743, DFID ENAG294/832/837/001A).

Incorporating HDM-4 within a strategic planning maintenance framework (SPM)

Using economic models, such as HDM-4, effectively within road asset management also requires other techniques to combine the HDM-4 analyses with observed road conditions. Extensive research was undertaken at Birmingham on a template and its associated components for the operation devised for the task, known as SPM, and the use of Multiple Criteria Analysis to modify the HDM-4 economically derived standards to suit the socio-political demands of the road user (references 4 and 5). Initial work on this aspect was funded by an EPSRC “Link” project (1998-2000: GR/L99814) and was subsequently implemented for the first time in Malaysia.

It was also identified that for an assessment of network condition a further model was required in parallel with HDM-4 and to that end NETCOM was the first stochastic modelling approach that was developed (1993 – 1995: DEFRA R185/93) and was succeeded by STRAT-2 (2000-2001: EPSRC "Link" GR/N37384) to give network behaviour in a powerful way for the use of decision makers.

Using HDM-4 as a research tool

HDM-4 has been used as a research tool in since 2007 at Birmingham including investigating the potential impact of climate change on road deterioration and maintenance requirements, addressing maintenance backlog, the deleterious effects of corruption in the road sector; and economic basis for the design of pavements on tropical soils (reference 6).

Fundamental PhD research continues at Birmingham with a focus primarily on enhancing road deterioration models. Additional research at Birmingham was carried out to see how HDM-4 could be incorporated within a strategic maintenance planning framework and also how HDM-4 could be implemented in any particular country or region

The lead researchers in this body of work have been: Professor Martin Snaith (Chair of Highway Engineering, until 2002); Professor Henry Kerali (Professor of Highway Engineering and Management, until 2006); Dr Jennaro Odoki (Senior Lecturer 2002-2010); Dr Harry Evdorides (RF, then Lecturer, from 1994 to present date); and Dr Michael Burrow (RF, then Lecturer, from 1998 to present date).

All of the relevant research for HDM-4 was led by academics at Birmingham.

3. References to the research

Research to develop HDM-4 and its constituent models

1. Kerali, H.R., Lawrance, A.J., and Awad, K.R. (1996). Data analysis procedures for long-term pavement performance prediction. Transportation Research Record (1524). pp 152 – 159.
2. Odoki, J.B, Kerali, H.R., and Santorini, F (2001). An integrated model for quantifying accessibility benefits in developing countries. Transportation Research Part A: Policy and Practice 35 (7), pp 601-623
3. Odoki, J. B. and Akena, R. (2008). Energy balance framework for appraising road projects. Proc. ICE Transport, 161(1): 23-35. doi: 10.1680/tran.2008.161.1.23

Incorporating HDM-4 within a strategic maintenance planning maintenance framework (SPM)

4. Snaith, M.S. (1998). The development and implementation of pavement management systems: a case study over 15 years. Procs of the Institution of Civil Engineers, Transport Board, Paper 11605, Institution of Civil Engineers, Vol. 129, Issue 2, London, pp 72-79.
5. Burrow, M.P.N, Evdorides, H., Savva, M., and Wehbi, M. (2013). The benefits of sustainable road management: a case study. Proc. ICE Transport. doi:10.1680/tran.11.00075

Using HDM-4 as a research tool

6. Evdorides, H., Nyoagbe, C., Burrow, M.P.N. Strategies to clear road maintenance backlog (2012). Municipal Engineer, Institution of Civil Engineers. Volume 165 Issue ME4. pp 205–213. doi.org/10.1680/muen.12.00003

References 1, 2 and 5 best indicate the quality of the underpinning research

4. Details of the impact

The Birmingham research led to the development of HDM-4 which is a widely used tool for road investment appraisal and decision-making, generating improvements in public policies and services. Developing countries are major beneficiaries of the tool, which is the *de facto* standard used by the World Bank for their road investment decisions and has been used to assess more than 200 of their projects since 2008. The success of the software has led to the commercial success of HDMGlobal, a consortium which manages the distribution and development of HDM-4 under exclusive licence from the World Road Association-PIARC. HDM-4 has also been utilised for economic assessment and road systems investment management in the UK.

Road investment appraisal in developing countries with HDM-4

HDM-4 has achieved wide uptake through being adopted as the World Bank's *de facto* standard for appraising road investment proposals from the developing world. HDM-4 is included as the sole Highway Development and Management Tool and Highway Design and Maintenance Standards Model on the World Bank list of Road Software Tools (http://go.worldbank.org/FF0CT8M770). HDM-4 has been used similarly by other multilateral and bilateral agencies. Developing countries have benefited from HDM-4 as it provides an economically-based objective means for road agencies and donors to appraise road investment and thereby identify road building and maintenance projects, which if funded through grants or loans, will create economic and welfare improvements.

Since 2008, the World Bank has reported to the University that it has used HDM-4 to assess over 200 funded projects, with an estimated total value of approximately US$55.16 billion, of which about $29.5 billion were World Bank loans, credits or grants. For example, the World Bank used HDM-4 to assess the € 306 million Northern Corridor Transport Improvement Project (225 km sections of Mombasa – Malaba/Kisumu roads in Kenya; and the road feasibility and design studies for the rehabilitation of the Lodwar– Nadapal 248 km highway in Kenya where the World Bank provided a $ 4.0 million loan to meet the cost of the feasibility and design studies for strengthening and upgrading of the road link (source 1).

HDM-4 has also been used by lead organisations in developing countries to justify proposals they make to attract investment from international donors. For instance, in 2009 HDM-4 was used to determine the costs and benefits of the long-term maintenance of the African North-South Corridor Aid-for-Trade road network, an important 8,600km road network connecting Dar-es-Salaam in Tanzania to the copper-belt of Zambia and the ports in southern Africa. The resulting analysis, and further assessment through HDM-4, was used to prioritise road upgrading projects on the network and also to determine the financial and economic rates of return on projects in the wide context of the Corridor as a whole. This latter aspect formed part of the case put forward by TradeMark Southern Africa (the regional economic body) to win over $600m investment in the Corridor from international donors by June 2013 (sources 2 and 3).

Governments throughout the developing world use HDM-4 routinely for road investment appraisal. For example, in Uganda, it has been used since 2010 to review the design, cost and economic benefit of upgrading 836 km of roads to bituminous standard (source 4). In Bangladesh, the Roads and Highways Department have used HDM (III, then 4) for the last 14 years to assess annually the maintenance needs of its highways and district roads and to prioritize maintenance expenditure so that the most economically beneficial roads are given the highest priority. (source 5)

Since 2008 more than 350 senior executives from over 30 countries have been educated through the World Bank-conceived and approved mechanism for the dissemination of road sector research, known as the Senior Road Executives Programme held in Birmingham. The programme curriculum includes the fundamental concepts associated with HDM-4. The executives are primarily from developing countries and are in decision making positions; their education in the HDM-4 methodology will have added to their contribution to their countries' economic development (source 6).

Commercial impact through HDMGlobal

Following the initial success of the HDM initiative, HDMGlobal was established in 2005 as a new consortium to commercialise HDM-4; its commercial success is a further result of the Birmingham research. HDMGlobal is based at the University of Birmingham Research Park, and is a consortium of the University, Atkins and URS-Wilson with other partners from the UK, Australia, France and Chile. The consortium was initially given a five-year concession by the World Road Association-PIARC for the exclusive right to distribute HDM-4 from June 2005; following the success of HDM-4 Version, PIARC extended this for a further five years in 2010.

Since 2008, HDMGlobal sold more than 1440 licences for HDM-4: 600 to countries with special economic needs; 450 to other countries; 110 to academic institutions; over 180 educational

licences to commercial training institutions; and 100 other licences. This has generated an income of £1.6m for the consortium, of which over £0.4m has been paid to the World Road Association-PIARC in royalties. (sources 7 and 8) The organisations which make up the consortium are regularly commissioned to undertake assessments using HDM-4 and provide training.

Exploitation of HDM-4 in the UK

HDM-4 has also been used to feed into assessments of the value for money achieved from road investment in the UK. The Department for Transport (DfT) commissioned an assessment completed in 2009 using HDM-4 to analyse the English local road network to quantify their long-term maintenance needs and assess the effects of different maintenance funding levels on the condition of the network and costs to road users. HDM-4 was adapted and calibrated to provide accurate results for England and linked with the DfT's database to facilitate strategic analysis. (source 9)

HDMGlobal have also utilised the research on the strategic planning maintenance framework to work with the DfT on the current Highways Management Efficiency Programme (www.dft.gov.uk/hmep). The outputs from this include freely available software to demonstrate the impact of investment in maintenance on road condition, which could facilitate shifts in public budgets in favour of road maintenance.

Work to develop equipment to collect accurate data for input into HDM-4 at low cost has ultimately led to the accreditation in 2013 by the UK Transport Research Laboratory of a new Chinese-developed data collection vehicle. The Birmingham researchers have continued the development of the SPM component systems which combine the HDM-4 analyses with observed road conditions to enable the use of HDM-4 in road asset management to be fully exploited by a road agency. Working with Highway Management Services Ltd and Key Traffic Systems (a major developer of highway software to UK local authorities), the component management systems have been redeveloped; this allows data collected by TRL-accredited vehicles, such as the one noted above, to be seamlessly imported into the systems and easily used for HDM-4 analysis and these systems are now being used to manage the road maintenance of two London Boroughs. (source 10)

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Corroboration statement received: Regional Director for South Caucasus, The World Bank, 1818 H Street, NW, Washington DC 20433, USA.
2. Corroboration statement received: Programme Manager, TMSA, Pretoria, South Africa.
3. J. B. Odoki, M.Anyala and R. Akena (2009). Economic Benefits of an Efficient North-South Corridor. Final Report for the RTFP Project Management Unit (PMU).
4. Corroboration available from: Director, Zulu Burrow, PO Box 31923, Lusaka, Zambia.
5. HDM Circle (2012). Maintenance and Rehabilitation Needs Report of 2012 – 2013 for RHD Paved Roads. Roads and Highways Department, Government of the People's Republic of Bangladesh. Available from the University.
6. Data available from University of Birmingham records.
7. Corroboration statement received: Technical Director, W S Atkins, The Axis, B1 1TF
8. Corte, J-F (Secretary General of PIARC). (2009). HDM-4 – A success story and new prospects. Routes-Roads, No 344, The World Road Association, Paris, pp 72-73. Available from the HEI.
9. Reported in Odoki, J. B. and Akena, R. and Bunting, E. (2013). HDM-4 adaptation for strategic analysis of UK local roads. Proc. ICE, Transport. doi.org/10.1680/tran.9.00026.
10. Corroboration statement received: Director, Keysoft Solutions Ltd, Alcester, Warwickshire B49 6DP.